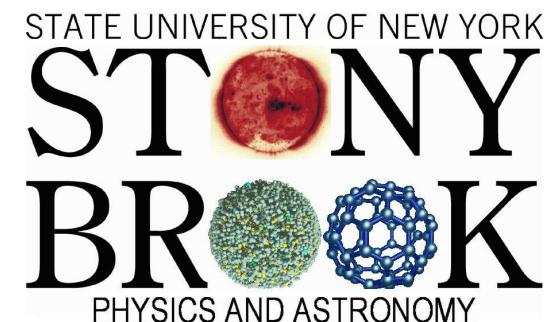

Direct γ -h Correlations in 200 GeV p+p Collisions with the PHENIX Detector

Matthew Nguyen for the PHENIX Collaboration
APS Spring Meeting
April 15, 2007

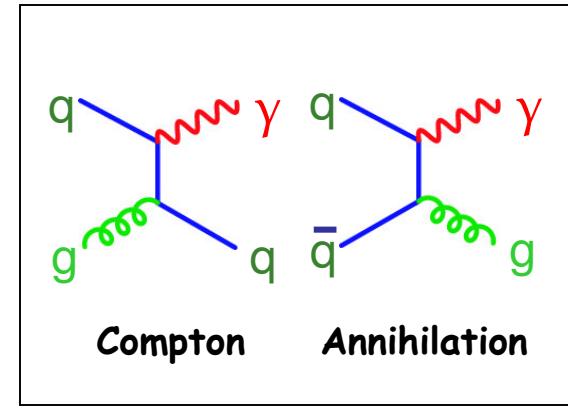


Why Direct Photons Correlations?

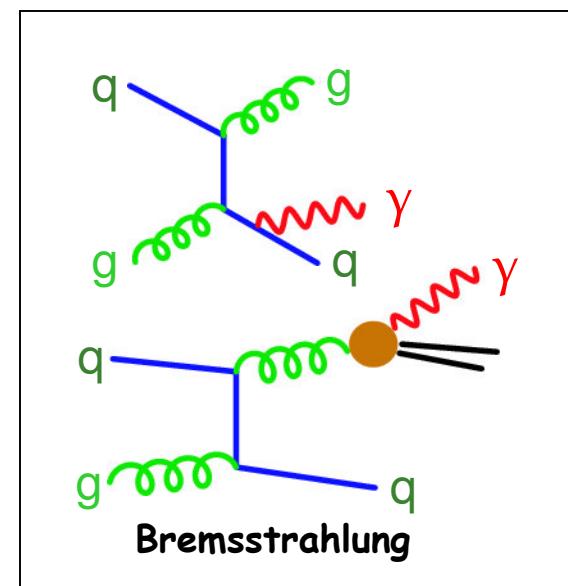
- p+p: Direct Photon Correlations measure the Fragmentation Function (FF) of quarks:

$$D(z) \equiv dN/dz; \quad z = p(\text{fragment})/p(\text{jet})$$

- A+A:
 - Modified Jet Fragmentation
$$\tilde{D}(z) \approx \frac{1}{1-1/\Delta E} D\left(\frac{z}{1-\Delta E/E}\right)$$
Wang, X.N., Nucl. Phys. A, 702 (1) 2002
 - The Golden Channel?
- Beyond Leading Order (the fine print)
 - Fragmentation plays a role
 - FF for photons not very well constrained
 - Initial state effects (k_T)

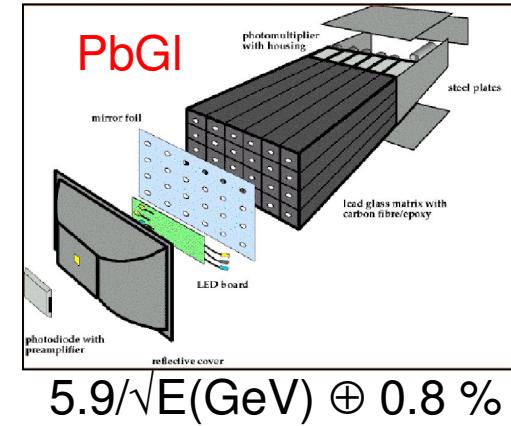
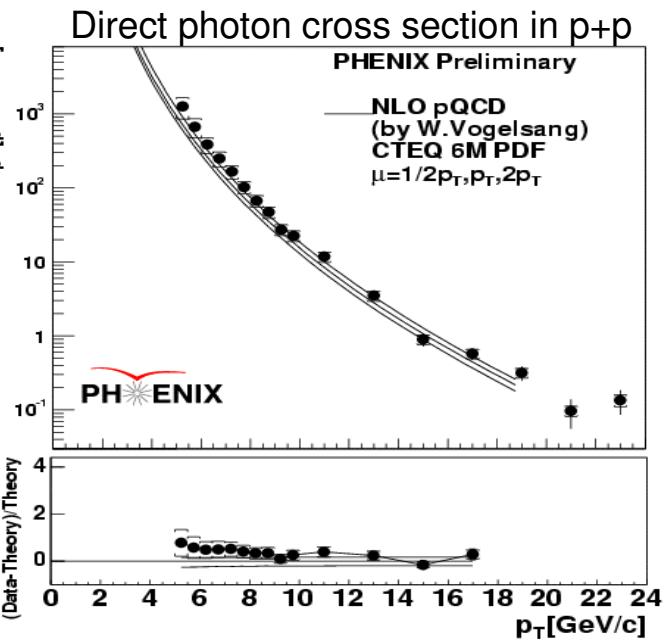
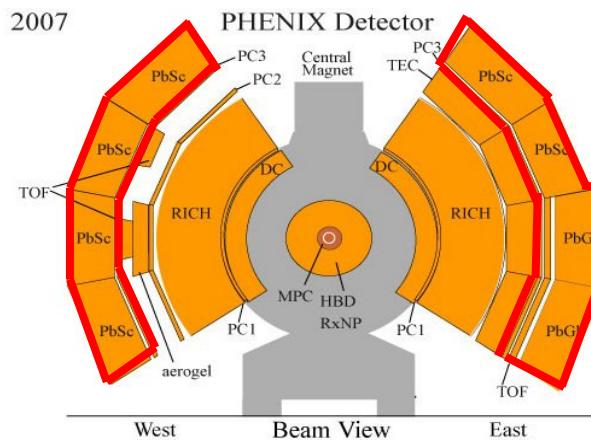
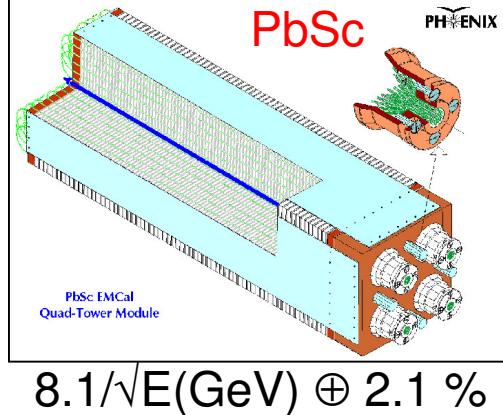


Direct Photon Processes



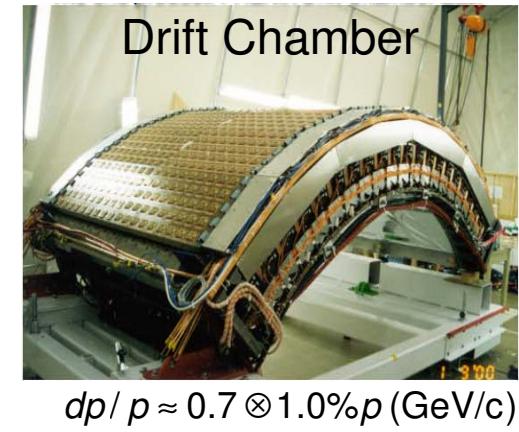
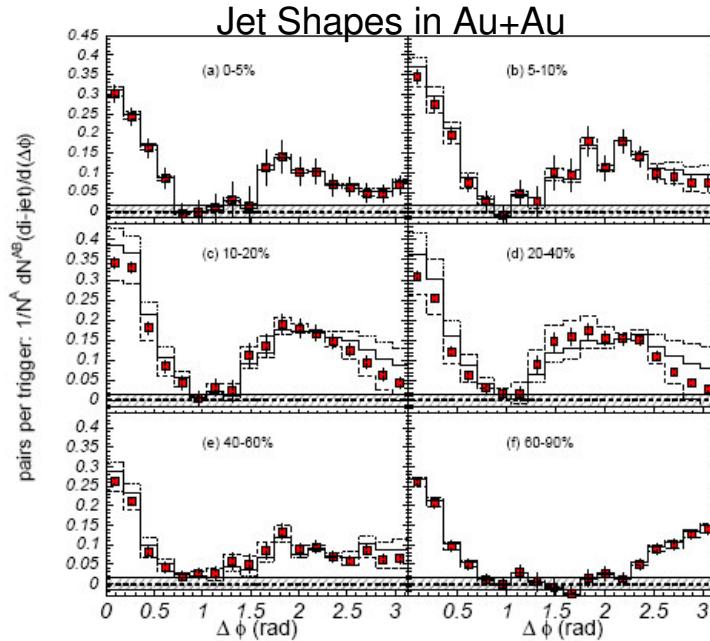
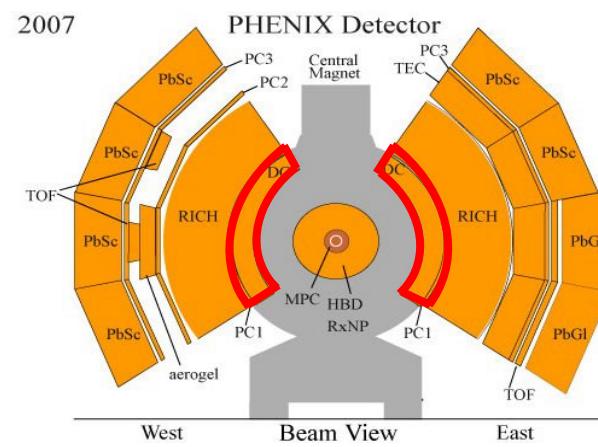
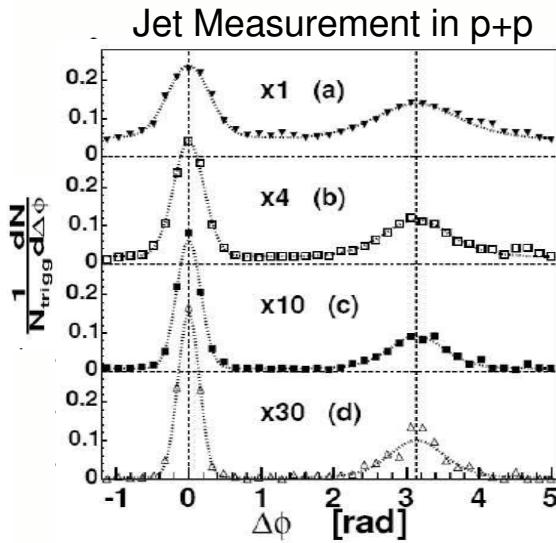
Photons in PHENIX

- Two types of highly segmented EM calorimeters > 24K towers
- Photon and π^0 measurements at very high p_T
- Cross sections agree reasonably with NLO calculations



Jets in PHENIX

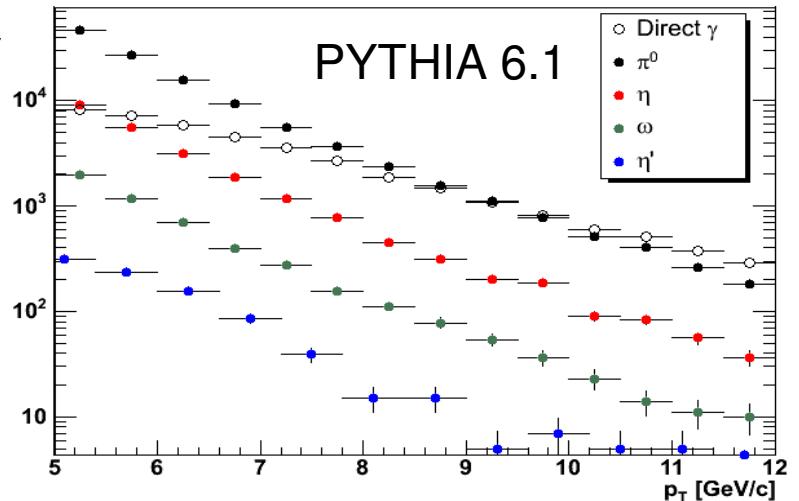
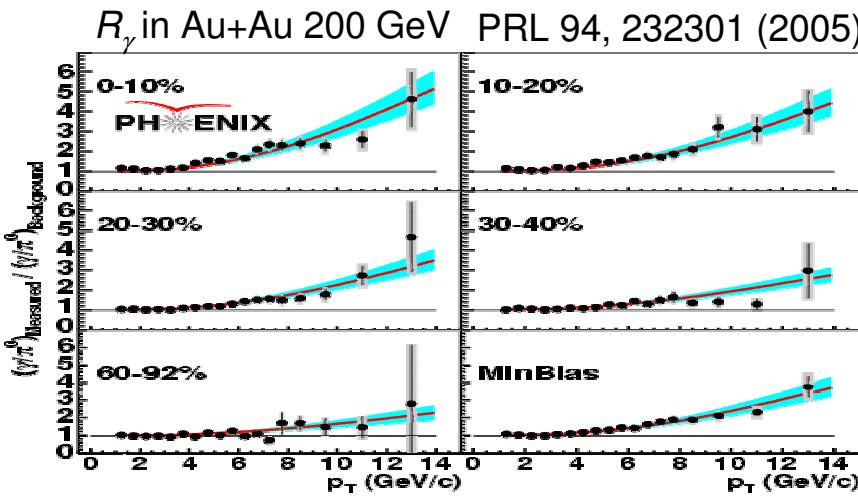
- PHENIX Tracking System – Drift, Pad Chambers
- Precise two particle correlation measurements in p+p and A+A
- Yet poor sensitivity to the fragmentation function and energy loss ΔE



γ -jet – The Experimental Challenge

- Large background from meson decay
- $R_\gamma = N(\text{inclusive}) / N(\text{decay})$
- Can perform a ***statistical subtraction*** of associated yields:

$$Y^{\text{direct}} = \frac{R_\gamma}{R_\gamma - 1} Y^{\text{inclusive}} - \frac{1}{R_\gamma - 1} Y^{\text{decay}}$$



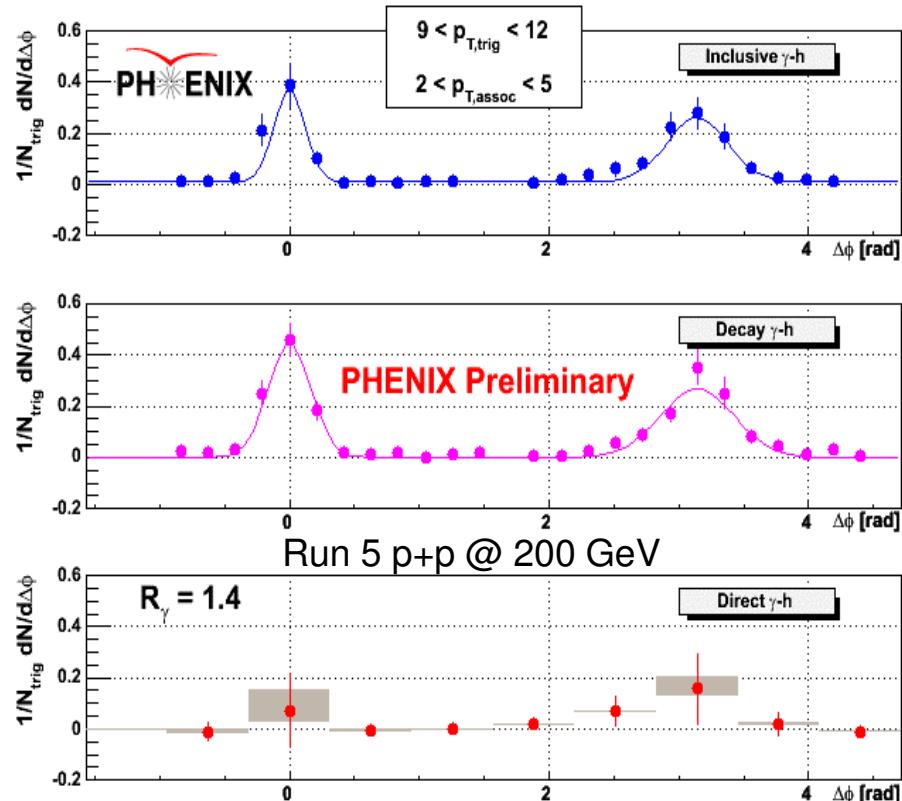
- Method well-suited for high multiplicity environment (A+A)
- However Y^{direct} very sensitive to uncertainty in R_γ
- Isolation cuts will improve precision but may not be possible in A+A

Constructing the Decay Background

- Quark Matter 2006 – Demonstrated we could construct the decay correlation from π^0 -h
- Decay kinematics reproduced by Monte Carlo including energy resolution effects (P)
- π^0 tagging efficiency also must be taken into account (ε)
- What about contributions from other hadrons?
→ This approach assumes they have the same conditional yield

Per-Trigger Yield from $\gamma(\pi^0)$

$$Y_{\gamma(\pi^0)}(p_T^\gamma, p_T^h) = \int \varepsilon(p_T^{\pi^0}) P(p_T^{\pi^0}, p_T^\gamma) Y_{\pi^0}(p_T^{\pi^0}, p_T^h) dp_T^{\pi^0}$$

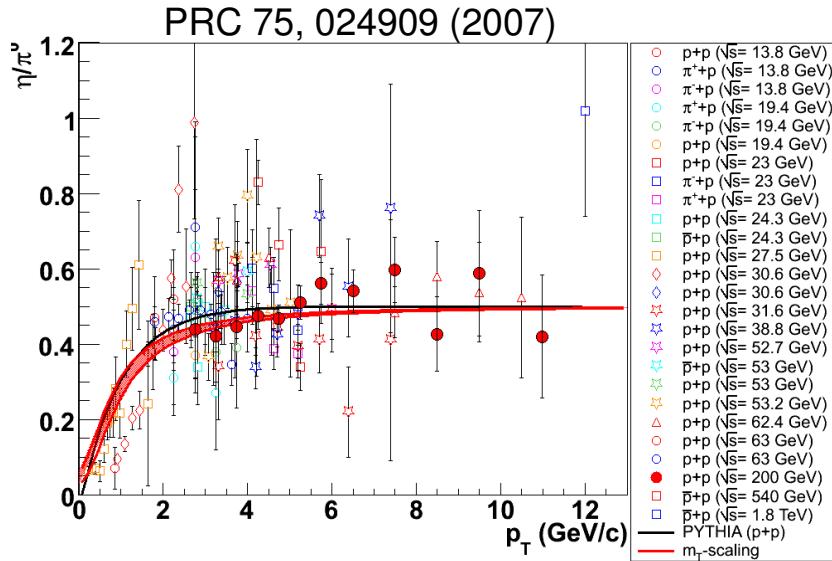


η -h Correlations

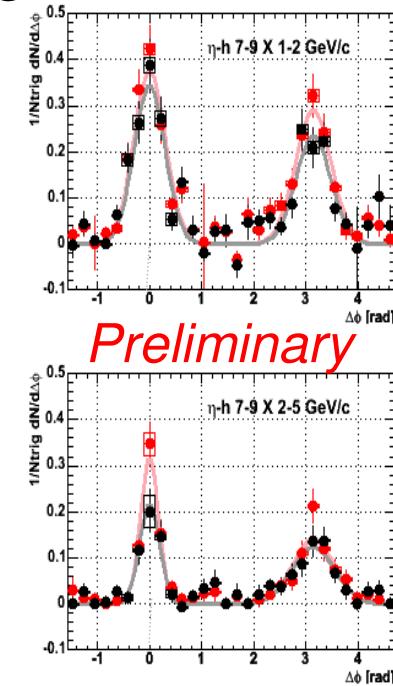
Daughter-h

Parent-h

- First measurement of η -h correlations at RHIC!
- $\gamma(\eta)$ -h Yields generated by same procedure as $\gamma(\pi^0)$ -h



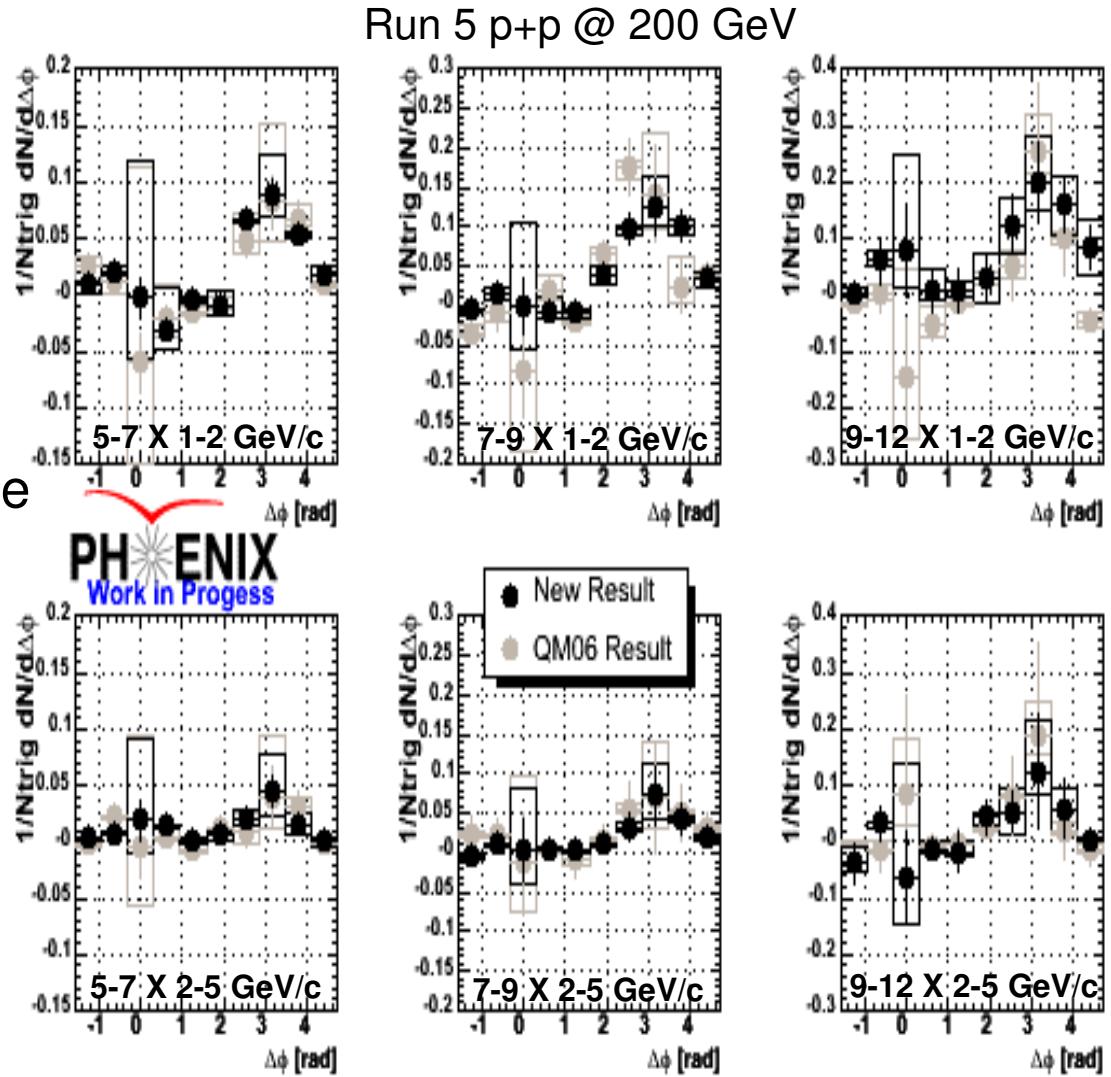
Run 5 p+p @ 200 GeV



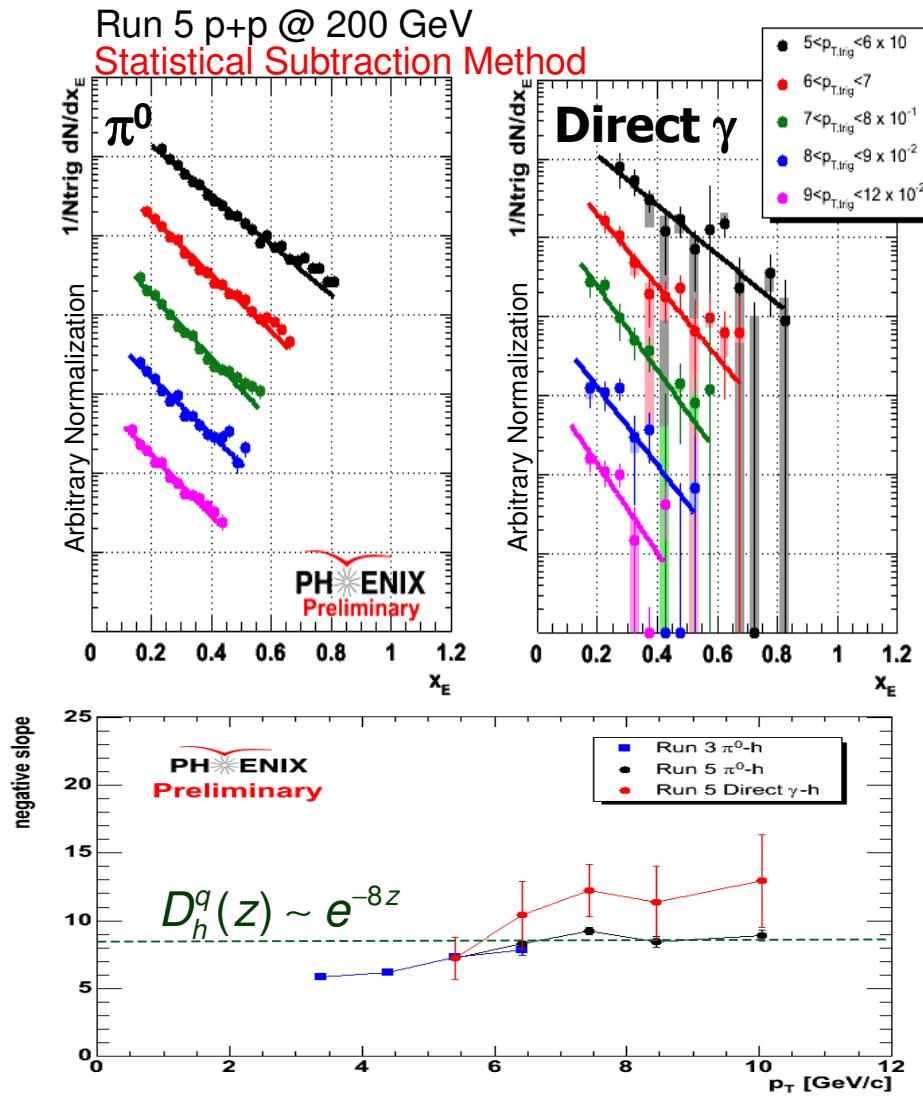
- η/π^0 measured in PHENIX – consistent with world data and m_T scaling
- η, π^0 account for $\sim 95\%$ of the decay background

Direct γ -h Correlations

- Signature small near-side correlation signal apparent
- Yield sensitive to η contribution at the near-side
- New η corrected results consistent with QM result within systematic error
- Still room for some fragmentation contribution



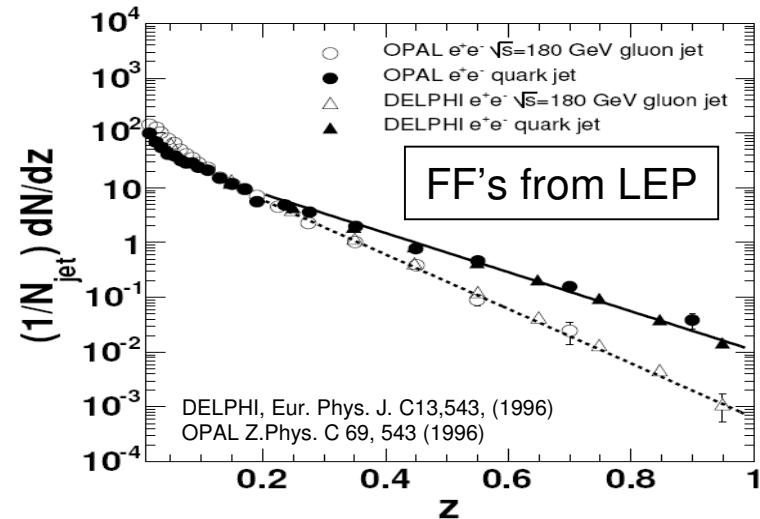
Towards the Vacuum Fragmentation Function



$$x_E = \frac{\vec{p}_T^\gamma \cdot \vec{p}_T^h}{|\vec{p}_T^\gamma|^2} = \frac{|p_T^h|}{|\vec{p}_T^\gamma|} \cos(\Delta\phi) \approx \frac{|p_T^h|}{|p_{jet}|} \propto z$$

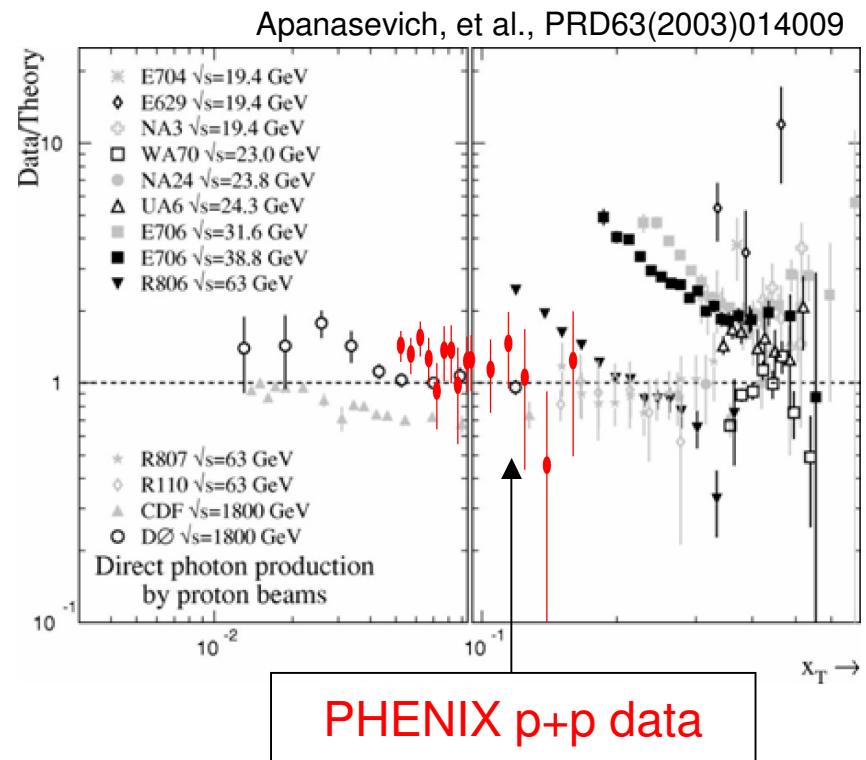
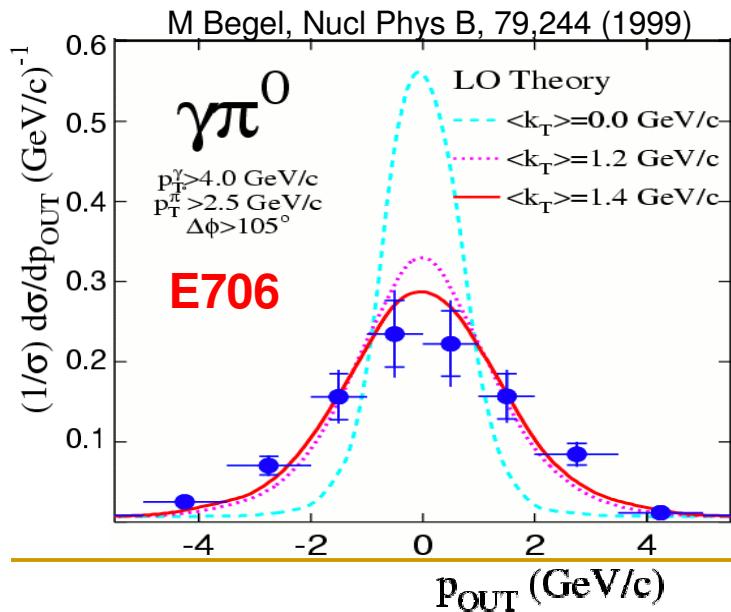
$$\therefore \frac{dN}{dx_E} \Big|_{p_T^\gamma} \stackrel{?}{\propto} D_h^q(z)$$

Perhaps this is not quite the whole story ...



What about the k_T ?

- Causes acoplanarity of jets and can modify the spectrum of final state jet fragments
- Theory claims to have k_T under control, but to what precision?



- PHENIX measured k_T for dijets
- Different for γ -jet than dijets
- Our $k_T(\gamma\text{-jet})$ measurement coming, stay tuned ...

Conclusions

- γ -jet studies in p+p at RHIC are moving beyond proof of principle phase towards precision measurement phase
- Isolation cut studies will allow more precise measurements
- k_T measurements will enable access to the quark fragmentation function
- Experiment should provide constraints for NLO calculations
- γ -jet in p+p, p+A, and A+A will be a challenge for both theory and experiment – Interesting times lie ahead!

Backup

ISR Results

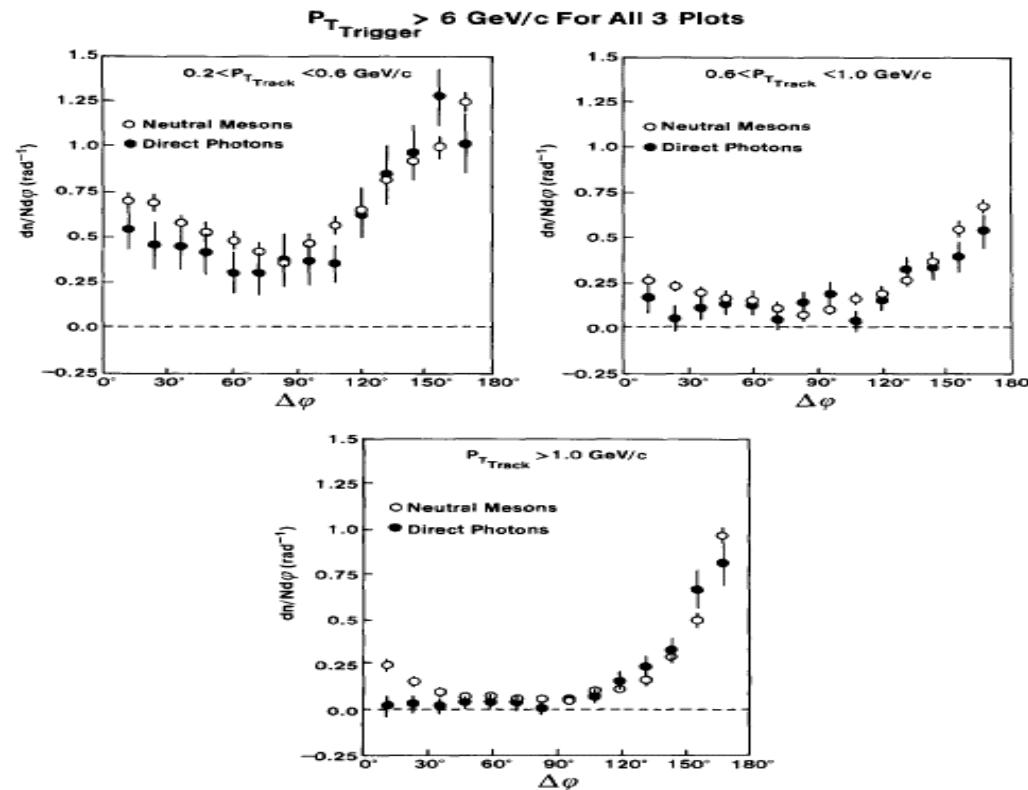
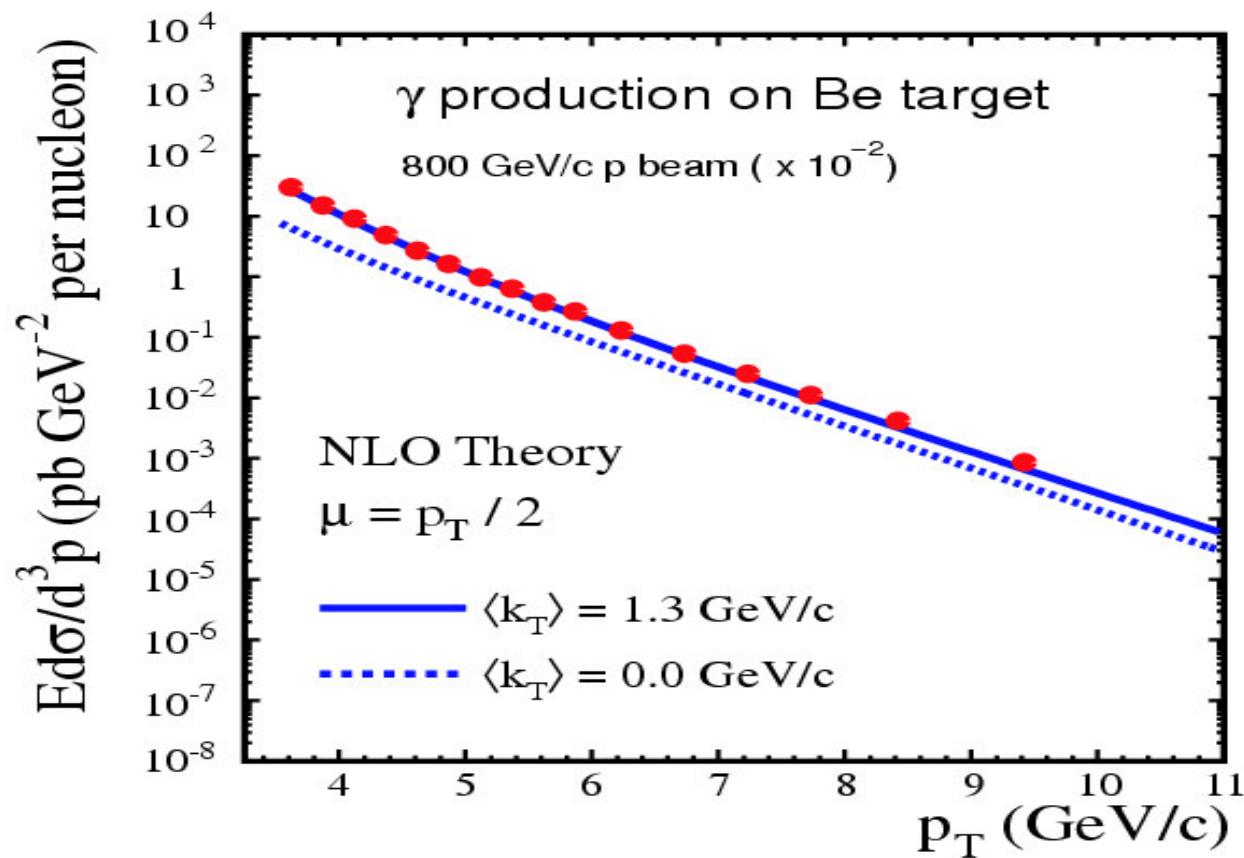


Fig. 15. Azimuthal distributions of charged associated particles for the direct photon and neutral meson samples (after background extraction) for $P_{T\text{Trigger}}$ greater than $6.0 \text{ GeV}/c$ and for three different $P_{T\text{Track}}$ ranges.

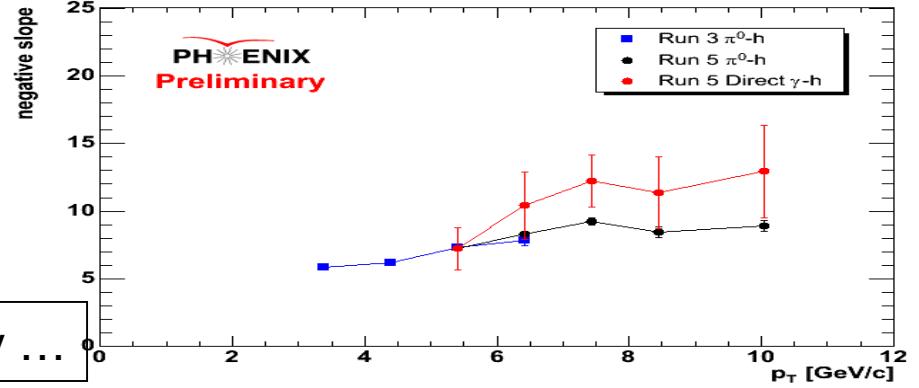
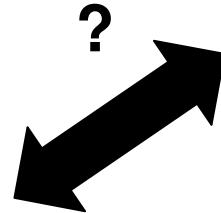
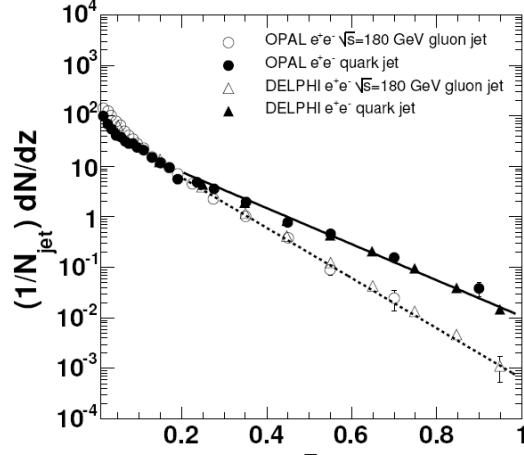
Cold nuclear effects



Alternate FF

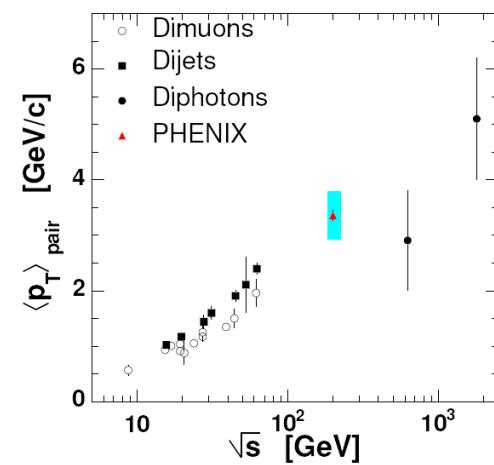
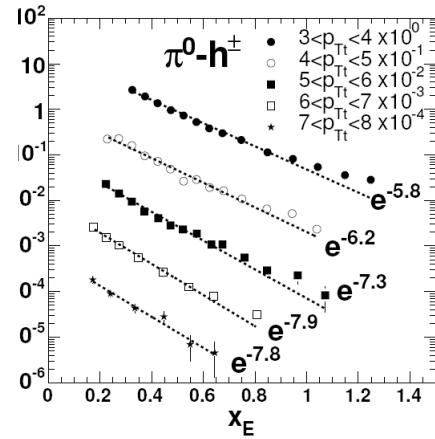
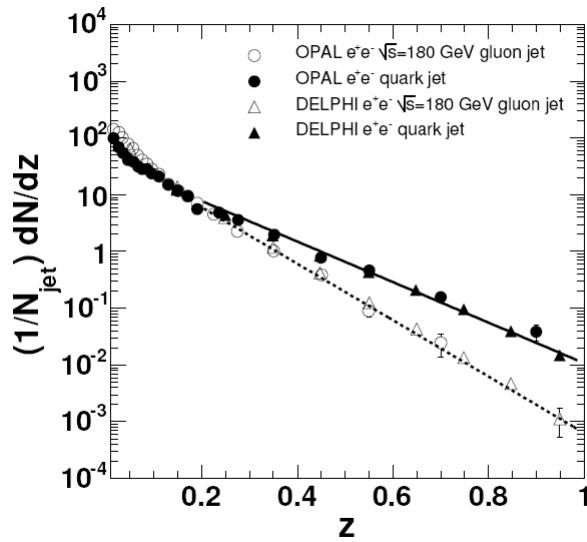
$$x_E = \frac{\vec{p}_{Tt} \cdot \vec{p}_{Ta}}{|\vec{p}_{Tt}|^2} = \frac{p_{Ta}}{p_{Tt}} \cos(\Delta\phi) \approx \frac{p_{Ta}}{\hat{p}_{Tt}} \propto z$$

$$\therefore \left. \frac{dN}{dx_E} \right|_{pTt} \propto D_h^q(z)$$



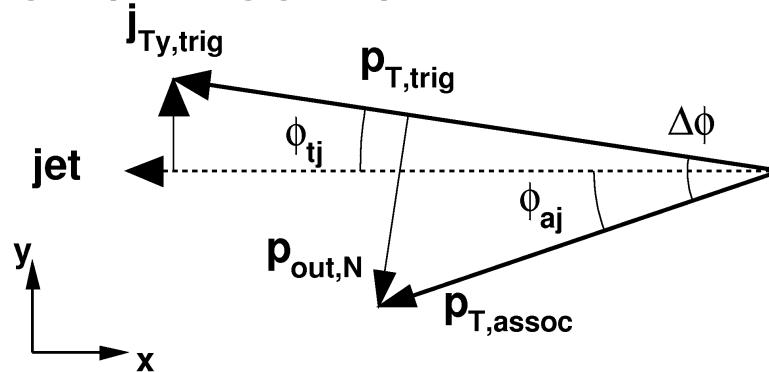
This is not quite the whole story ...

More FF, k_T data

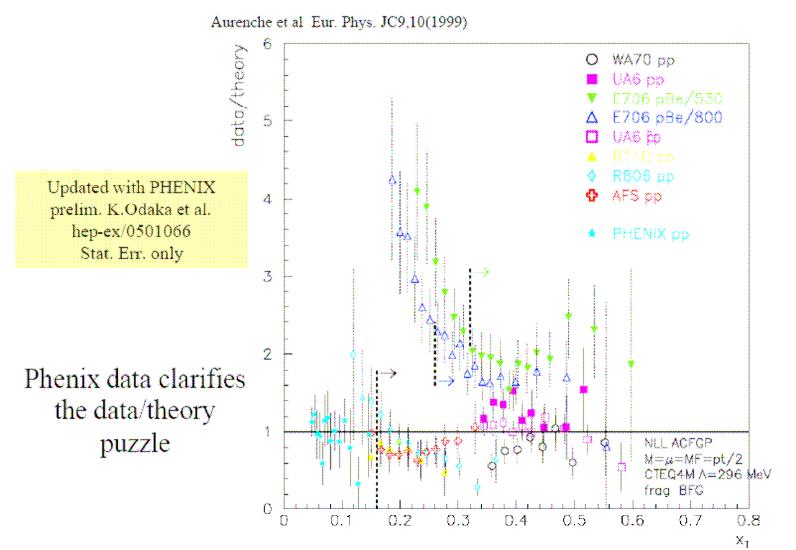


P_{out} cartoon

P_{out} is transverse momentum of 2nd
wrt high-pt trigger particle

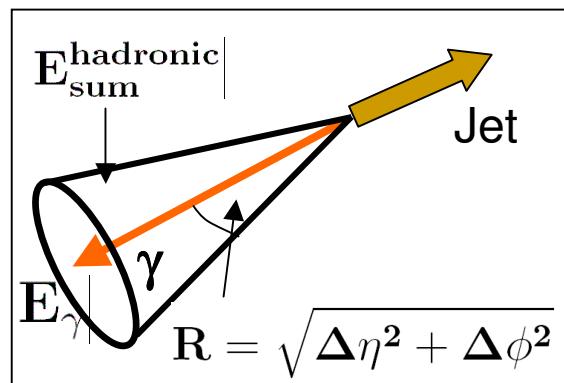
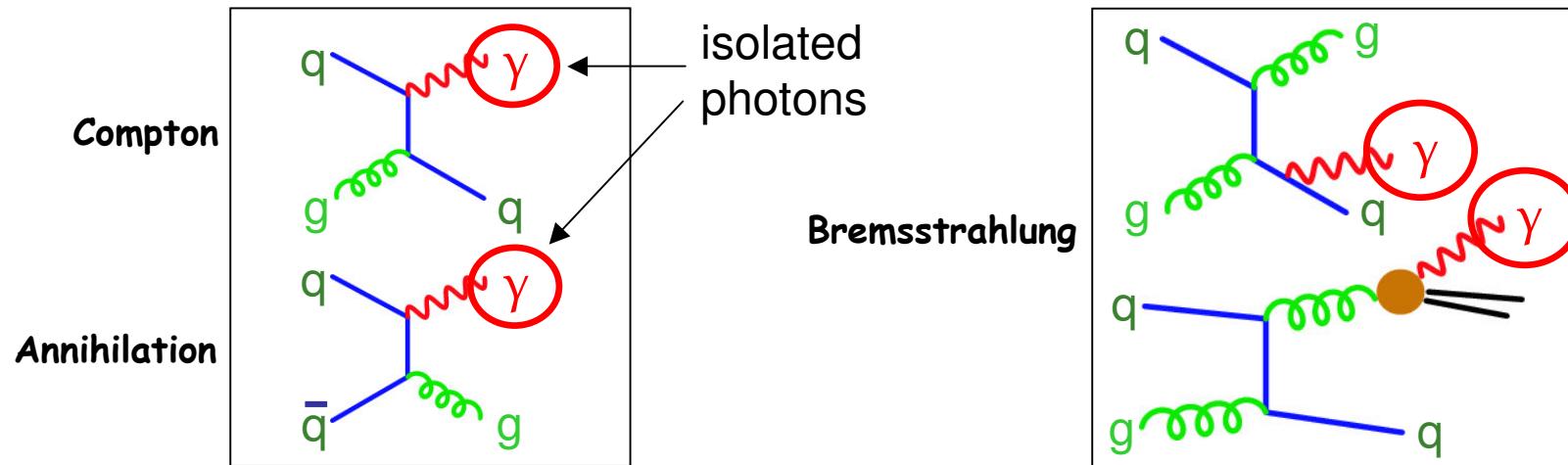


Another x_T Comparison



M. Verlan

Isolation Cut Method (Stolen)



- Isolation cut removes Bremsstrahlungs photons

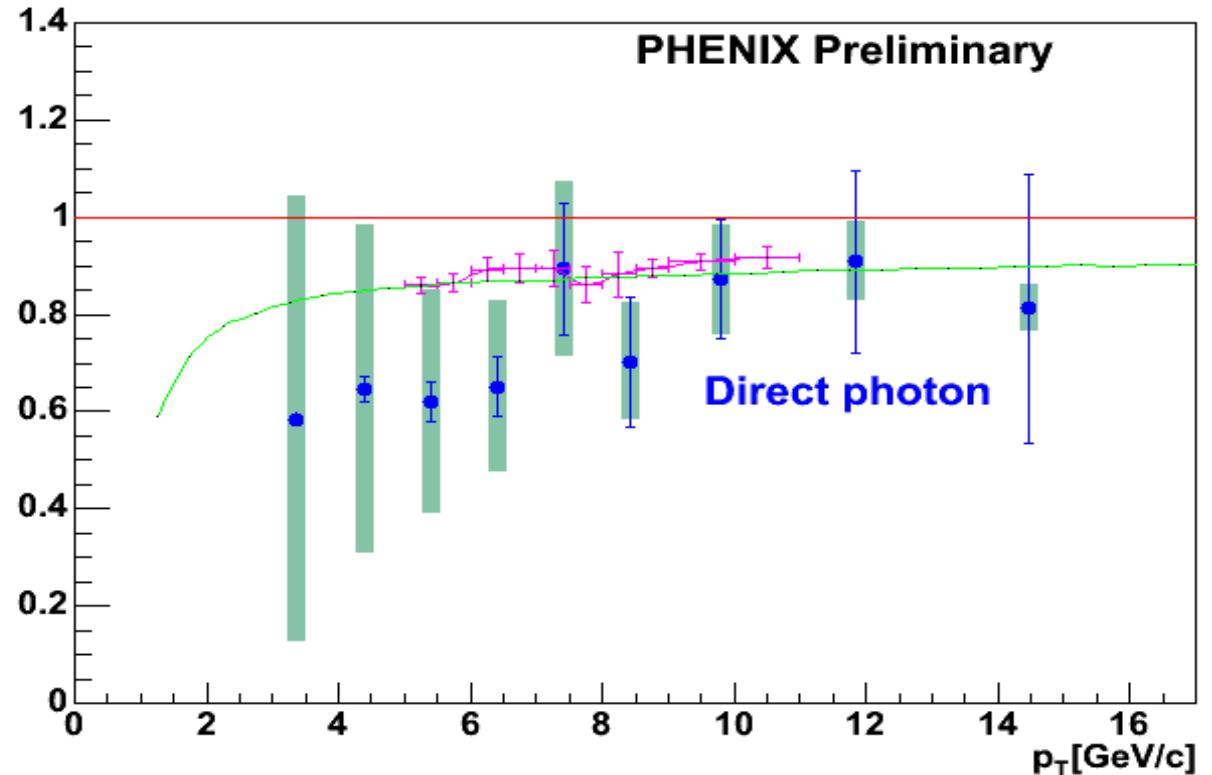
$$E_{\text{sum}}^{\text{hadronic}}(R < 0.5 \text{ rad}) < 0.1 \times E_\gamma$$

Isolation Cut vs. pQCD (stolen)

Isolation cut
 $0.1*E_\gamma > E_{\text{cone}(R=0.5\text{rad})}$

+ By M.Werlen,
JETPHOX
 $-.35 < y < .35$
 $\mu = p_T$
BFG set2, CTEQ6M

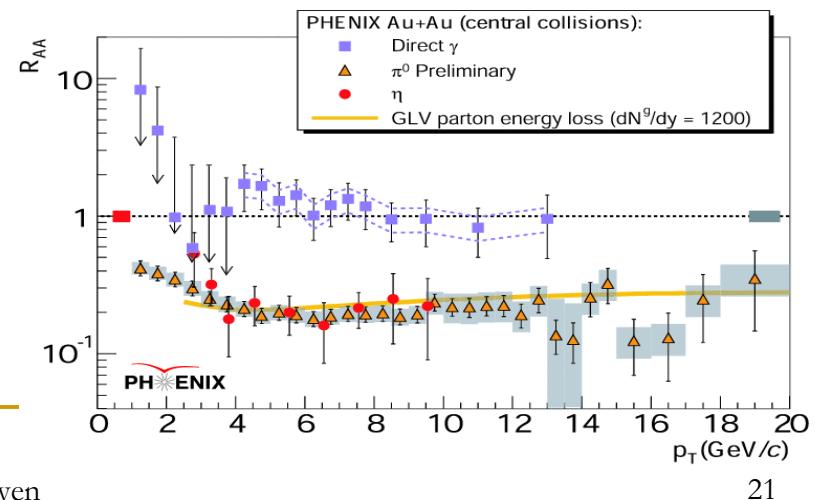
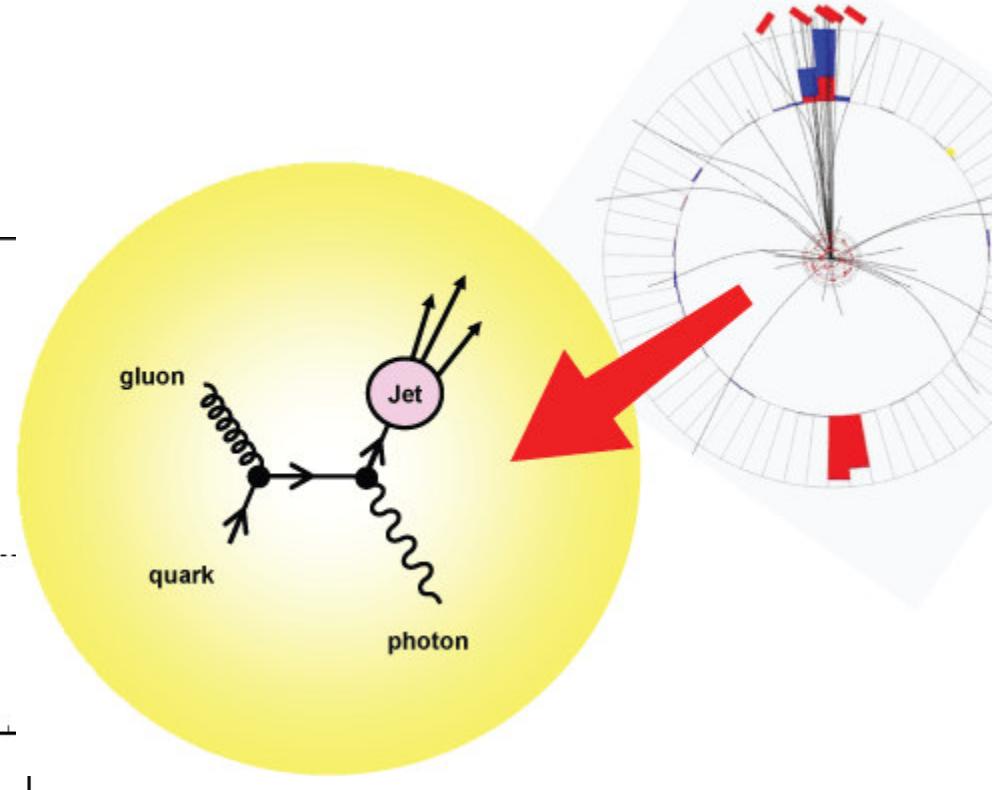
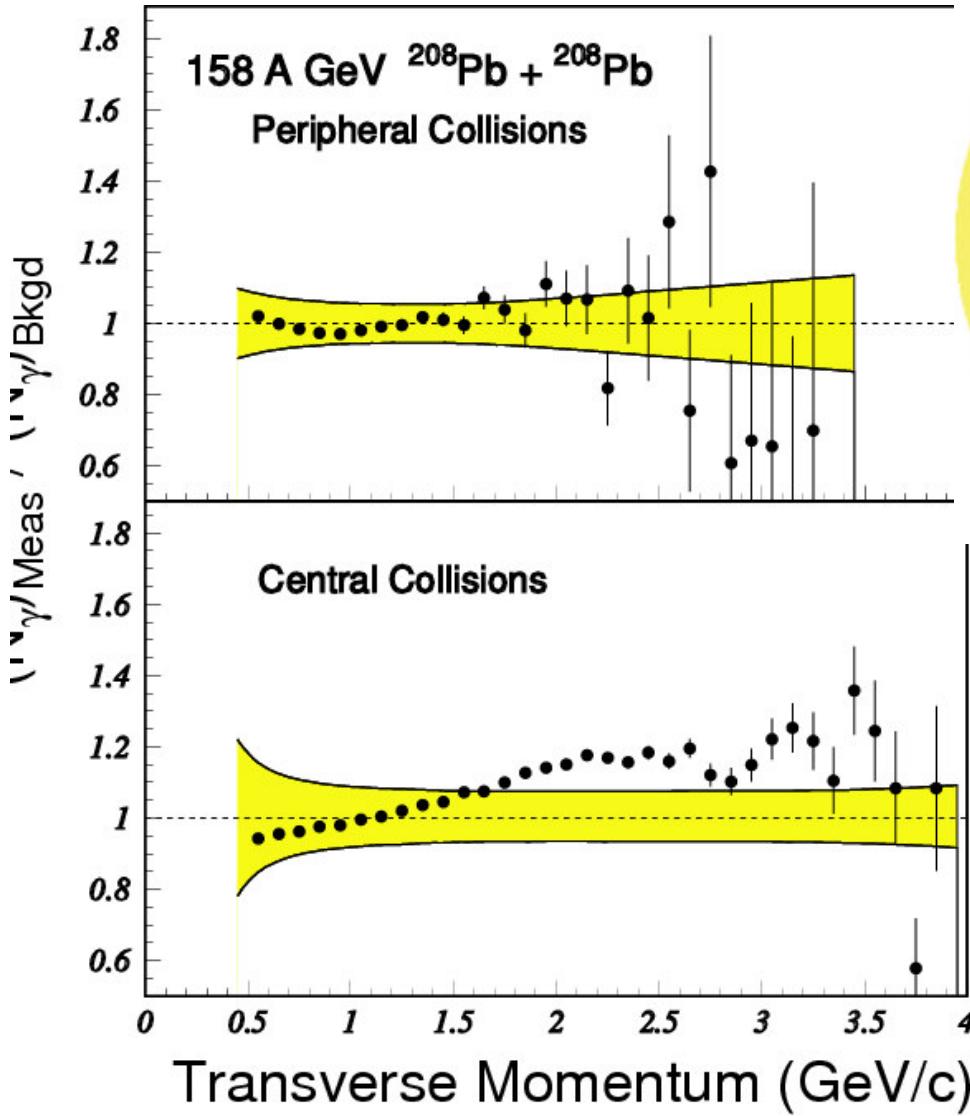
— By W.Vogelsang,
 $R=0.4$
 $\mu = p_T$, CTEQ6M



Although our systematic uncertainties are large:

pQCD predictions (with isolation cut)
consistent with PHENIX data

Some extra stuff



Nguyen